Fermi National Accelerator Laboratory

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Research Division Flammable Gas System Calibration Procedure and Stability Studies

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Flammable Gas Alarm System

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Calibration Procedure for the

Model SC100 Combustible Gas Smart Sensor

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The SC100 Combustible Gas Sensor and the DC110 controller (General Monitors, 3037 Enterprise Rd., Costa Mesa, CA, 92626) form part of the flammable gas detecting systems installed at Fermilab.

Calibration of the SC100 sensors to the customer specified gas is initially performed at the factory. The operational life time of this units is of the order of 5 years and they carry a 2 year manufacturers warranty. The main cause of failures is the catalytic bead sensor poisoning - loss of sensitivity with time due to foreign substances from the environment (the most dangerous is silicon greases or lead containing chemicals). For this reason, the overall performance and need for re-calibration are affected by many environmental factors and the actual recommendation from the manufacturers is to establish for each particular application it's own recalibration period.

The Operational manual for the SC100 unit specifies that re-calibration is required every 90 days. This period is not based on any specific technical reason, as concluded after contacting the manufacturers.

Most of the units at Fermilab have been installed for a period longer than 2 years. No detailed analysis had been previously performed of the stability of their calibration.

In order to assure the proper sensor operation and to investigate possible changes in the sensor sensitivity for the purpose of establishing a re-calibration period the following procedure was developed:

1.- Permission is obtained from the Research Division Head to bypass some flammable gas system alarms.

2.- The bypass key is issued by the Operation Center and the experiments involved are notified that a calibration will take place.

3.- The Fermilab Security Dispatch is informed of the alarms to be bypassed.
The DC110 controller is set in the Alarm bypass mode.

4.- The standard gas mixture, 50% of Lower Explosive Limit (LEL), of Ethane, Methane or Isobutane (according to the gas used in the particular experimental area) is applied to the sensor and a reading taken in the DC110 Readout/Relay Module.

5.- If the reading is between 45% and 55% LEL this is noted down and no re-calibration takes place.

6.- If the reading falls outside the range indicated above then the SC100 sensor is re-calibrated with the standard gas mixture to 50%, or replaced if this value can not be obtained.

7.- The Fermilab Security Dispatch and the Operation Center are notified that the calibration has been completed.

8.- Alarms are restored to the operating mode.(see note), and the bypass key is returned to the Operation Center. (Note: restore alarms only when DC-110 read 0% LEL.)

9.- The procedure above is to be repeated twice at 90 days intervals.

10.- Depending on the results of the calibration above the interval is to be extended to 180 days for a new re-calibration.

11.- A re-calibration period will then be established.

Experimental Results and Discussion of the SC-100 Combustible Gas Smart Sensor Calibrations

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All flammable gas sensors in the fixed target experimental areas were calibrated to 50% of Low Explosive Limit (see note 1) by the manufacturer prior to the installation at Fermilab. The majority of the sensors throughout the fixed target experimental areas were inspected four times during the period from November 28, 1990 to April 6, 1992. The 50% of LEL gas mixture was applied to the sensors and reading from DC110 readout module was recorded. For the detailed procedure see part 1 of this document and the SC100 manual.
The summary of it follows.

The total number of sensors installed in the fixed target experimental areas - *84.*

1. Date: November 28 to December 5, 1990.

Number of sensors measured: - 0
80 sensors were calibrated only.No sensitivity measurements were taken (4 sensors in lab G needed cable repairs).

2. Date: February 27 to March 11, 1991.

Number of sensor measured: 83
One sensor in MP9 was unaccessible. Only those sensors with readings of 50% LEL gas mixture less than 45% or greater than 55% were re calibrated, the rest of the sensors were measured for sensitivity. In other words, no calibration was done with the detectors reading between 45 and 55% of 50% LEL gas mixture.

Note 1.
LEL is the abbreviation for Low Explosive Limit which means the minimum concentration of gas in the gas - air mixture capable of starting a fire.

3. Date: June 18 to June 26, 1991.

Number of sensors measured: 68,
16 sensors located inside interlocked enclosures were not accessible.

4. Date: April 6, 1992.

Number of sensors measured: 79,
Sensors access to which required special arrangements were not measured (i.e. sensor mounted on top of the magnet).

Important note.

A reading of 50% LEL by SC100 sensor which is less than 40% or more than 60% was arbitrarily established by the authors as abnormally high or abnormally low reading.

No obvious correlation was observed between such factors as location and/or serial number of the SC100 detectors and the results obtained. Heads with abnormally high (more than 60%) readings or abnormally low (less than 40%) were randomly distributed over areas with different environmental conditions and different groups of serial numbers.

The histogram of results is shown on figures 1, 2 and 3. The number of sensors outside the acceptable range (from 40 to 60%) is 6 for the first set of readings, 4 for the second set and 6 for the third set. There was no overlap between sensors outside the acceptable range for all sets. That is 6 sensors from the first set with the readings less than 40% or more than 60% are different from those in the second set and are different from those in the third set. Also there was a failure of a readout module (DC110), and several cases of blown fuses on gas permit chassis power supplies.

Note 2.

Sensors with abnormal readings did not require replacement. They were calibrated and checked for sensitivity, all of them gaving a reading within 5% of 50% LEL.

The results of Gaussian distribution fit to the experimental data are summarized below:

set of measurements	1	2	3
date	02.27.91	06.18.91	04.06.92
degrees of freedom	18	18	18
r.m.s. deviation	4.16%	3.01%	3.04%
center of distribution	50.8%	49.7%	48.15%
chi squared per deg. of freedom	2.28	1.82	0.81
distribution	Fig. 1	Fig. 2	Fig. 3

confidence level is 90% for all sets.

Note 3.

A sensor with reading between 40% and 60% we consider normally operating, all others are failures.

Note 4.

The interval of readings taken into Gaussian fit is from 40% to 60%.

Results of the Gaussian distribution fit show that average sensitivity of the normally operating detectors shifted by only 2.65% since the first set of measurements was done. This corresponds to the 2.65% shift over 13 month period. To establish a re calibration period for the SC100 sensors we have to take into consideration the number of detectors which either failed or with their sensitivity drooped more than 10% (that is the number of detectors with reading of 50% LEL less then 40%). The number of such detectors is 3 for the first 90 days since they were re calibrated for the first time at Fermilab on December 5, 1990, 3 for the second test interval (120 days), 6 for the third test interval (270 days). Total is 12 sensors over 480 days.

Conclusions.

The number of detectors which shifted from initial 50% LEL calibration by more than 5% over 90 days period is small enough in order to increase the time interval between calibrations at least to 120 days, but with any further increase in time between the calibrations probability of SC100 failure greatly increases. In order to keep the number of detectors with abnormal sensitivity low, we would recommend 120 days to be the maximum allowable interval for our present environmental conditions.

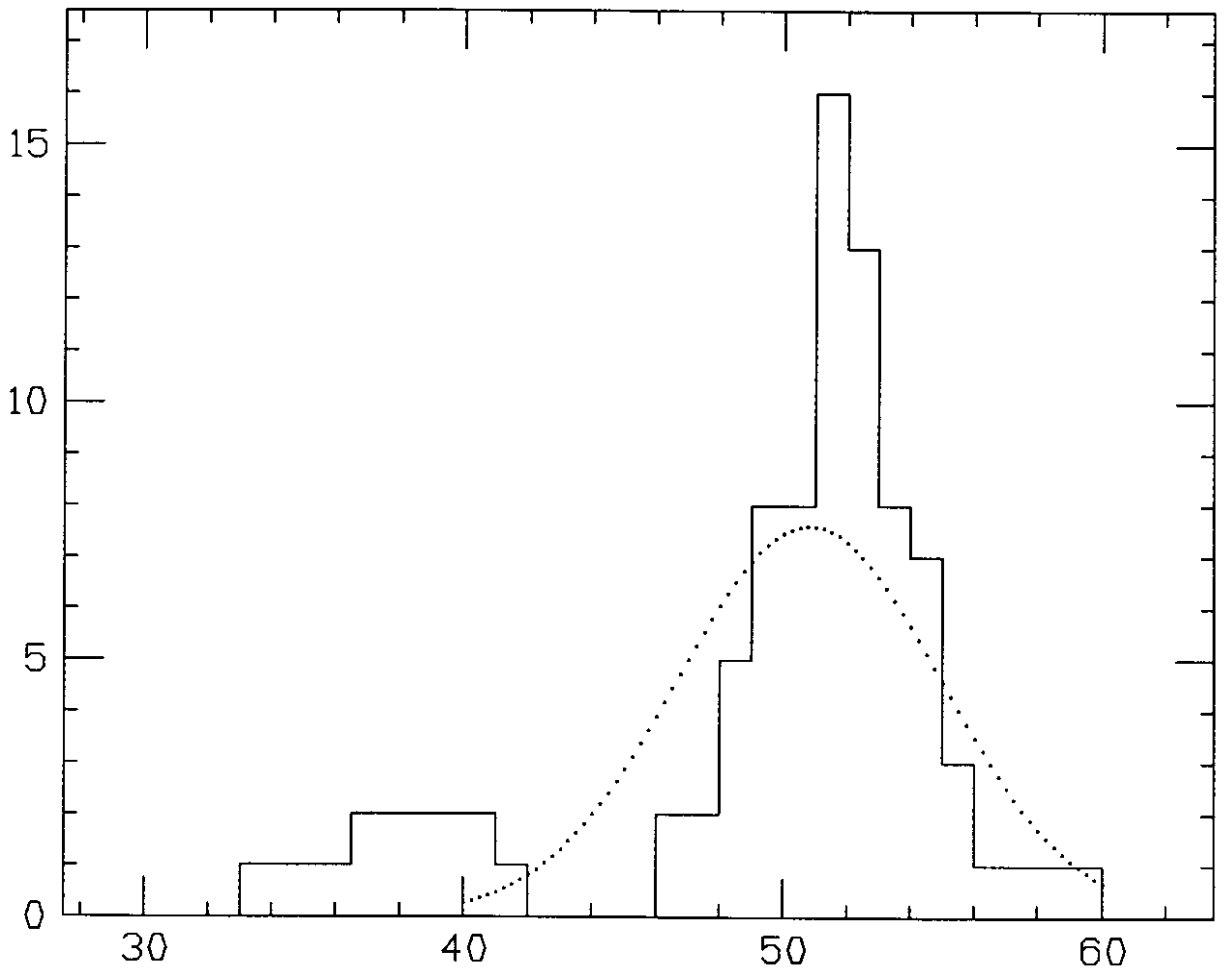

Figure 1 - the first set of measurements, February 1991.

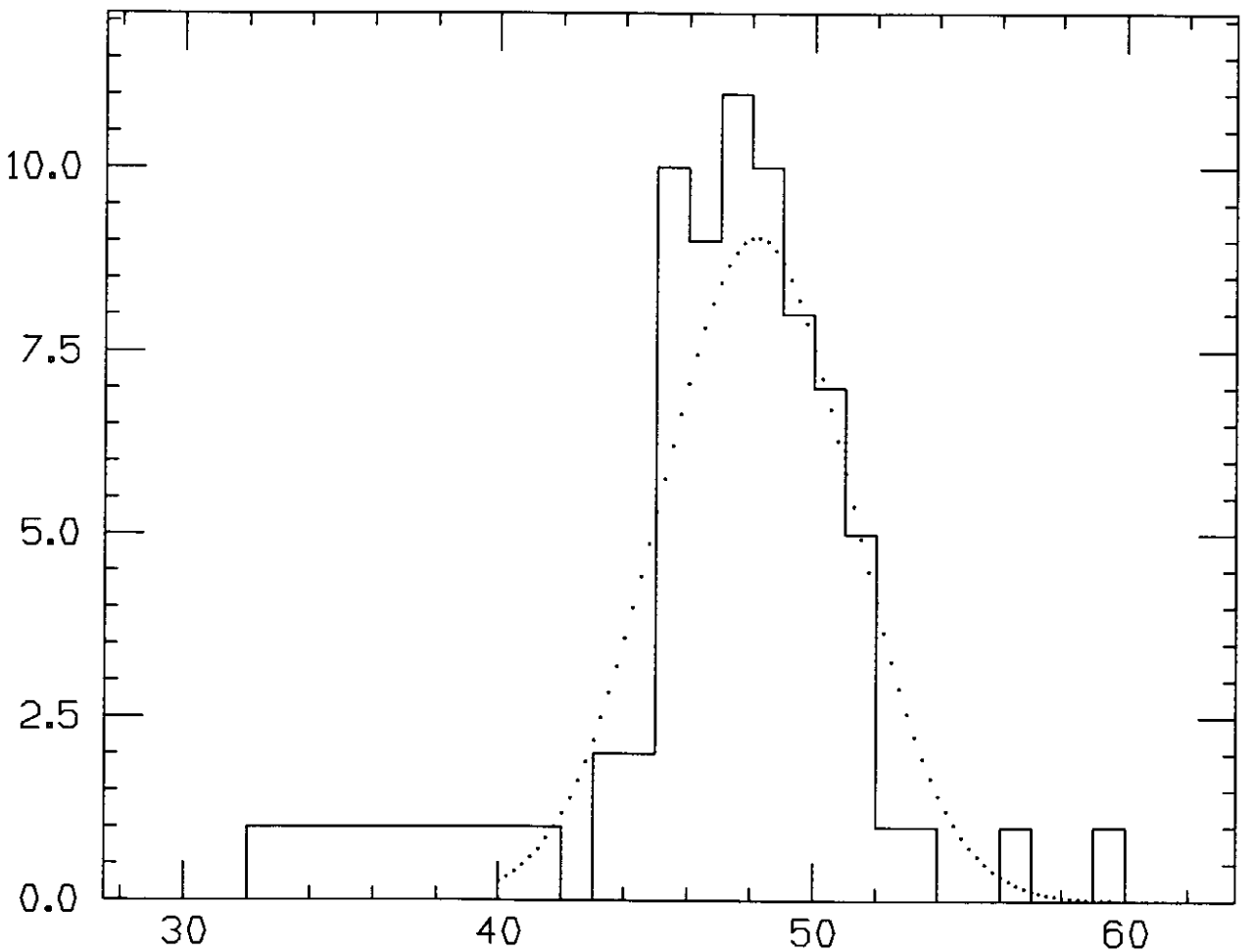

Figure 2 - the third set of measurements, June 1991.

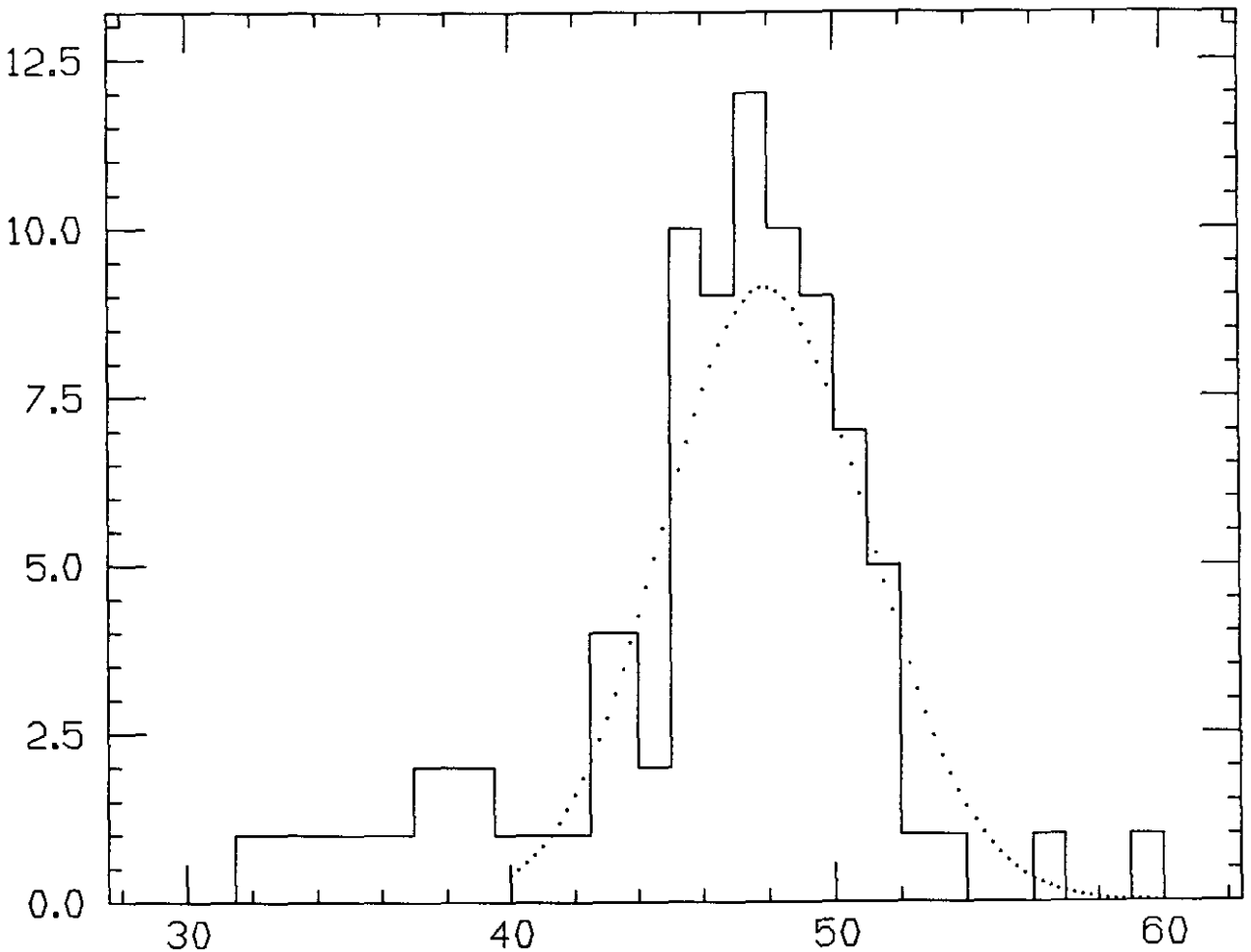

Figure 3 - the third set of measurements, April 1992.